

Design Concept of Day Minus 1 Production Model Using Systems Modeling Language: a Case Study of Hospital Beds Production

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Abstract

This study is being conducted in a hospital bed industry to produce any kinds of hospital beds to fulfil demand of global market. This papers outlines the efforts taken to setup manufacturing execution system (MES) to integrate ERP and Manufacturing system of the company. The main objective of the study is to design WIP buffer supply materials system to implements mode D minus 1 production scenario using MES to achieve best company operational performance. The company has implemented ERP SAP R/3 enterprise with the moduls installed are FI, CO, SD, PP and MM. The installed ERP SAP system modules not fully fit with the operational manufacturing system and can't achieve the best performance. The system not able to provide production information and components supply completly in the right time for every stage of production. To propel the fitness of ERP SAP from the side of organization is interfaced Logistic function acting as GL function of ERP which is company not installed yet. For this purpose, is used SysML a general system modelling for create material supply system. Using SysML can be design a concept of MES model which is paired up with its manufacturing system and ERP System modules.

Keywords

D minus 1, Hospital Beds, MES, ERP SAP, SysML

1. Introduction

This Paper is part of a research on maintain work in process (WIP) buffers of production activity to produce various kinds of hospital beds. The data and information in the production floor is related with the order confirmaton from the customer , production planning to realize the order, production activity and Bill of Materials (BOM) and data of the products. The objective of this research is to support model D (day) minus 1 production scenario (Sudiro *et.al*, 2015) to succeed produce the goods as planned and on time delivery to the customers.

Model D minus 1 production scenario is shown in fig 1a. The " Day 0" being time scheduled to assembly the finished goods. Day - 1 is day scheduled on the upstream buffer WIP materials supply, consecutively implemented for every upper stream of the workstations buffer. Raw components supplied in lot and downsize in batch in WIP buffer to supply the welding stations, welding buffer in batch supply to paint shop and feed queuing in hanger. Coming out

from paint shop, the components are arranged in racks, trolley or box in batch of WIP buffer. This batch materials is sent to assembly station together with standard components supply from warehouse arranged in kiting form.

Timing scheme of this model is shown in fig 1b. In time D - 2 must be available WIP buffer as feeding material to welding plant. The result of welding process is wip buffer, this complete wip buffer must be available feed to paint shop, and result of paint shop are finish components which is fed to assembly line.

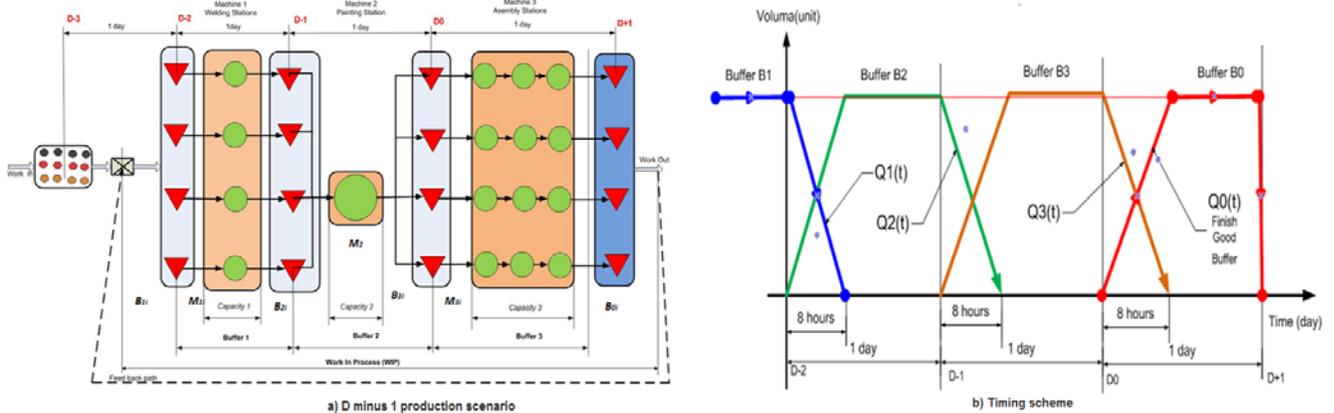


Figure 1. D minus 1 production scenario (Sudiro et.al, 2015)

The case study where the D minus 1 production scenario implemented is in a company which is use ERP SAP R/3 Enterprise with the modul used are Financial Accounting (FI), Controlling (CO), Sales and Distribution (SD), Materials Managements (MM), Production Planning (PP) the other modules not implemented yet. The ERP SAP is acronim of Enterprise Resource Planning (ERP) and Systems, Applications and Products (SAP). In this study the company implemented ERP SAP Sistem went live since July 2013, the result of implementation is not as well as expected. Especially in the production floor, information of every aspects of production in production floor not real time available. The information always late and the impact is waste in the production floor rise up drastically, also frustate of administration people which operating ERP SAP system because administration of operating the ERP SAP system slower then production time. The components have been reach assembly station but the information of the components still left behind, no data of the components have been issued or received in SAP data base, even the finish good have been receive in the ware house but without transaction document.

The worst case is in the end of the years, financial departements can not close the report because the huge differences of the stock on all production unit and very difficult to balance this stock differences. Cumulative stock differences in year 2014 is nearly 1.2 million US \$ and 2.8 million US \$ in 2015, this is make huge loses for the company. The company ERP failure is as the result of study done by Kringsman (2011) to investigate the rate of success of IT projects shows that in 2010, 61.1 % of ERP projects took longer than expected, in 74.1% of the cases costs exceeded budgets, and in 48% of the cases, projects registered benefits realization under 50%.

2. Methodology to Linking ERP and Production Floor

How ERP systems can be used to reduce uncertainty and improve operational performance, have been surveyed by Madapusi, A, D'Souza, D (2012), they state firms can achieve their operational performance objectives by choosing one or a combination of strategies. For example, firms can deploy a single module to a business area and obtain operational benefits. Alternately, firms can implement a combination of modules that addresses multiple business areas. The relation of ERP System Implementation Status with Operational performance shown in figure 2.

ERP system implementation status consist of 14 ERP modules identified in the literature as specified by Madapusi (2008) are: financials, controlling, plant maintenance, materials management, production planning, project management, sales and distribution, general logistics, quality management, human resources, supply chain management (SCM), customer relationship management (CRM), electronic-commerce(E-Commerce), and advanced planner optimizer/advanced planner scheduler (APO/APS).

Researchers have suggested that ERP implementation could have a significant influence on operational performance. These measures as specified by Madapusi (2008) are: information availability, information quality, standardization, inventory management, and on-time delivery. These five operational performance measures are represented by the response variables in the relationship depicted in Fig 2. A description of the performance measures is provided in table 1.

To effectively linking ERP system module with operational performance must be implement systemic concepts as describe by Gattiker & Goodhue (2004,2005) that ERP systems as a collection of highly integrated subsystems can be described as “tightly coupled”, in contrast to the “loosely coupled” subsystems that make up most of the installed base of pre-ERP systems in organizations. To be sure, tight coupling facilitates coordination among subsystems, and this is typically critically important in today’s competitive business environment.



Figure 2. Linking ERP system implementation status to operation performance (Madapusia A & D'sousab D, 2012)

Table 1. Description of performance measure (Madapusia A & D'sousab D, 2012)

| | |
|---------------------------|---|
| Information availability: | Information availability refers to the changes in the availability of integrated real-time information from the ERP system. |
| Information quality: | Information quality refers to the changes in the availability of consistent and reliable information from the ERP system. |
| Standardization: | Standardization refers to the streamlining and rationalization of business processes as well as information flowing through the firm. |
| Inventory management: | Inventory management refers to changes in the inventory management processes that lead to sizeable reductions in inventory holdings, increased inventory turnover, and better control over inventories. |
| On-time delivery: | On-time delivery refers to changes in the order management/order cycle that facilitate on-time delivery of products/services to customers. |

Galbraith (2002) suggests that firms should integrate their front-office and back-office operations through IS-based module extensions so as to enhance performance. Moreover, the findings from his studies suggest that firms which implement modular systems and integrate them over time will obtain improved performance benefits.

The results of Madapusi, A and D'Souzab, D (2012) study indicate that the contributions of different ERP system modules vary with different measures of operational performance and that a systemic ERP system implementation contributes to operational performance changes. Because performance varies with implementation status, it is important that managers focus on holistic integration to derive maximum systemic gains. It is the systematic combination of modules, rather than ERP implementation per se, that dictates performance enhancement. Their findings suggest that an 8-module ERP system provides optimal systemic benefits for the stereotypical firm in the Indian. The 8-module ERP are: Financials, Controlling, Materials management, Production planning, General logistics, Plant maintenance, Quality management, Advance planner optimizer/advance planner scheduler

Also linking ERP system module with operational performance can be seen from company activity from the lowest level (shop floor) to highest level (Company level) as state in ISA-95 standard (2000), the International Society of Automation defines a generic model of the eight activities of Manufacturing Execution Systems (fig. 3):

- Product definition management manages all information about the product required for manufacturing;
- Production resource management manages the information about resources required by production operations.
- Detailed production scheduling includes local planning and scheduling of production and resources;
- Production dispatching manages the flow of production by dispatching production to equipment and personnel.
- Production execution directs the performance of work, as specified by the contents of the dispatch list elements.
- Production data collection collects and manages process and equipment information.
- Production tracking prepares the production response for the ERP.
- Production performance analysis provides feedback about production.

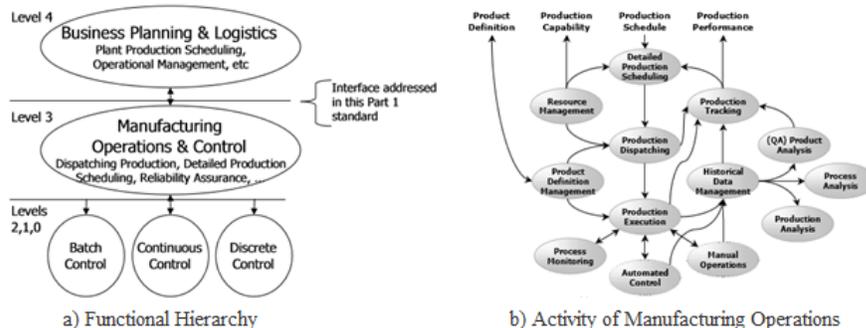


Figure 3. Activity model of MES (ISA 95, 2000)

Obviously, all these activities are not independent. They are integrated into common processes and they share and exchange dynamic information. Furthermore, each MES solution does not integrate every activity and each activity is more or less developed according to the type of industry (Snoeiij, J, 2006).

Thus, effectively linking ERP system module with operational performance can be done with implement MES which is integrated within a manufacturing system. This integration requires a modeling language able to represent software (MES and manufacturing system), hardware (manufacturing system) and their interactions. Today, the language best suiting this purpose is known to be SysML (Systems Modeling Language). It is a recent language derived from UML (Unified Modelling Language) dedicated for systems engineering applications. These systems may include hardware, software, information, processes, personnel, and facilities.

The model research in this study is MES model which is paired up with its manufacturing system and ERP System modules use SysML to answer research question:

1. How the existing ERP system module can be linking with operational performance of production use D minus 1 production model
2. How the existing ERP system module contributes to changes in performance of production use D minus 1 production model

3. Research Methodology

3.1. Requirement Assessment

To pair up a MES with a manufacturing system Pietrac et.al (2011) one has to model the typical internal structure of a MES application, the internal structure of the target manufacturing system, and the integration of this MES into an industrial domain (featuring an ERP, OPC servers, users...). The specifications need to be structured so as to make the connection between actors, the tasks to perform and the conditions under which these tasks are done Pietrac et.al (2011).

The existing condition of the industrial domain is still there is a gap between ERP system module suggested by Madapusi, A and D'Souza, D (2012) with company ERP system module as shown in table 2. ERP module Fi, Co, MM and PP is same with ERP module as suggested, the difference is in GL, PM, QM and APO/APS, module SD has assembled is strengthening the system.

Table 2: Gap of ERP system module

| | ERP Module Suggested [3] | Company ERP Module System | Another System |
|----|--|---------------------------|------------------------|
| 1 | Financials (FI) | Financials | |
| 2 | Controlling(CO) | Controlling | |
| 3 | Materials management(MM) | Materials management | |
| 4 | Production planning(PP) | Production planning | |
| 5 | General logistics(GL) | X | Ware House Managements |
| 6 | Plant maintenance(PM) | X | Plant maintenance |
| 7 | Quality management(QM) | X | Quality management |
| 8 | Advance planner optimizer/advance planners(APO/APS) | X | |
| 9 | Sales and Distribution (SD, wishes to be implemented) | Sales and Distribution | |
| 10 | Supply chain management (SCM wishes to be implemented) | X | Ware House Managements |

Module APO/APS significantly affect the information quality only and for this case can be discarded. QM has significant effect for the operational performance system, but QMS really is available in the company, company implement good manufacturing practices ISO 9001:2008 and ISO 13485:2003 but not integrated yet to ERP system. Plant maintenance except aspect information quality is significantly affect all aspect of operational performance. Plant maintenance has been assigned in organization but not integrated yet to ERP system.

General logistic effect to information quality, standardization and information availability. Inside organization this function not established yet, but logistic function is done by warehouse management. Also warehouse management play dual role as warehouse also as supply chain system (SCM), but these role not effectively could achieve high level operating performance because existing system can't detect availability or completeness of

components in every work station , there isn't system available to integrated warehouse of every work station to ensure that supply materials to every workstation are available completely in all aspect production that is :production schedule, kind of product, quantity, production line.

The existing condition potentially could be utilizing as success factor of ERP implementation by change role or of organizational functionality to integrate with ERP system. For this purpose, warehouse management integrated to General Logistic, also in organization of warehouse management change to Logistic with assigned task to handle warehouse, logistic, and to handle availability of WIP Buffer in every work station to assure that production process could be running well to achieve organization best operational performance.

Quality management and plant maintenance for this case not integrated yet in ERP system but both function are existing in company organization as integral part of manufacturing system which would be pair up with MES.

For the specific case of WIP buffer, the analysis of the production conditions is important in order to assure supply of materials outside or inside the manufacturing system. This analysis leads to identify the states, corresponding to a breakdown or operating time, and the state transition conditions. These transitions can be caused by the manufacturing system or the production staff, via a user interface of the MES or of the manufacturing system.

Finally, the study is carried out with exchanges of information between all (hardware and software) components that generate the system state changes observed from WIP Buffer angle.

3.2. SysML Introduction

The Systems Modeling Language (SysML) (Deligatti, L, 2012) is an extension of the Unified Modeling Language (UML), version 2 While UML is dedicated to software modeling , SysML is more general and is dedicated to system modeling (Deligatti, L, 2012). In practice, SysML is well suited for systems with interacting software components and hardware components, such as manufacturing systems, mechanic systems and embedded systems. SysML includes nine diagrams, partially covered by UML (see fig.4).

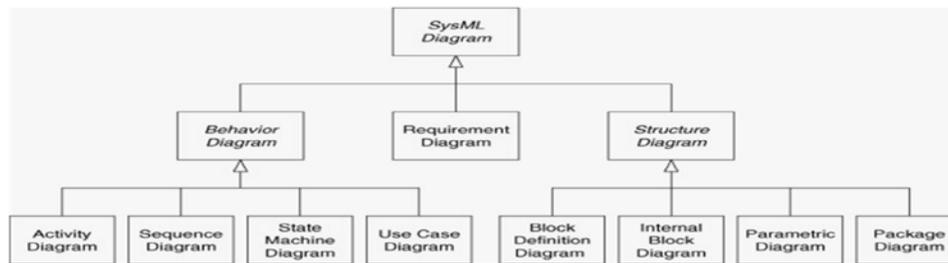


Figure 4. SysML diagram taxonomy (Deligatti, L, 2012)

3.3. Framework

This frame work adopted from Pietrac et.al (2011) study. They divide the development process of the performance analysis function and its pairing up with the manufacturing system into three main steps:

- The analysis of the existing manufacturing system and the customer's specifications which the MES shall answer to;
- The MES design with modifications of control programs of the manufacturing system
- Its implementation with the deployment of the solution and the final validation tests.

4. Case Study of WIP Buffer Control

4.1. The Manufacturing System

The study of the manufacturing system is an assembly plant located in a Hospital Bed Factory Company in Yogyakarta Indonesia. The company produce any kind of hospital furniture for this case the study focusing activity in assembly plant which produce hospital bed, the assembly activity consists welding process, painting, assembly (include packaging). The assembly plant provides 8 stations and pallet system for conveyed components or parts between each stations. It features consist three buffer and supply stations (B1, B2 and B3), three production stations (M1, M2 and M3), a buffer station (B0) for parking the packaged finish good before transfer to warehouse, and a controller station (C1) to dispatch and control production. Figure 5 illustrates this assembly plant schematic lay out.

The system is designed to be used by a plant manager and some workers. The role of the plant manager is, mainly, to plan production lots launching according to weekly production orders received from PPIC order, and to make the system produce better by way of WIP buffer analysis. Workers launch new productions, collect finished assemblies, monitor part stocks of stations B1, B2 and B3, and manage system functioning states.

B1 station is metal raw components receiving station as material supply to welding station. In this station the raw components be managed in raw components WIP buffer before supply to Welding station M1. At this station the raw components classified and grouped base on type of products formed from these components, the quantity to produce, its production line and supply schedule. This component group placed on a shelf, trolley, box or pallet. Handling information of these components are stored in the information system components. Welding process would be done if M1 has received information from information system components that all components to be supply are have been completely prepared (fit in type, amount, production line and schedule), available in pallet and ready to transfer.

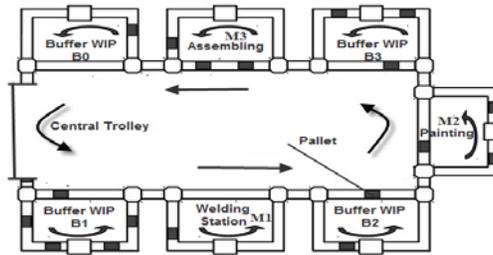


Fig 5. assembly plant schematic lay out

B2 station is semi-finished components receiving station as material supply to painting station. The semi-finished components be managed in semi-finished components WIP buffer before supply to painting station M2. At this station the semi-finished components classified and grouped base on type of products formed from these components, the amount, its production line and supply schedule. Information of handling of these components are stored in the information system components. Painting process would be done if M2 has received information from information system components that all components to be supply are have been completely prepared (fit in type, amount, production line and schedule), available in pallet and ready to transfer.

B3 station is finish components receiving station before the components to be assembly, this station also integrated with warehouse of purchased components which is acting as a supermarket to supply components to assembly line M3. In this station the finished components be managed in finish components WIP buffer before supply to assembly station M3. At this station the finished components classified and grouped by type of products formed from these components, the amount, its production line and supply schedule. This component group placed on a shelf, trolley, box or pallet, Information of handling of these components are stored in the information system components. Assembly process would be done if M3 has received information from information system components that all components to be supply are have been completely prepared, available in pallet and ready to transfer.

4.2. Analysis of Current Situation and Requirements

Figure 6 is global structure block definition diagram; this figure depicts the environment of the system to install. This diagram consist of manufacturing system, logistic system and raw component supply system. The MES has to be installed on a preexisting production system, with an ERP already present. The use of patterns enables to detail the domain and the other systems to install or adapt; in this case, in addition to the MES, we have to install an OPC server to communicate with interface computer controller and a database server to store MES data. The production system has to be adapted as it had not been designed to work with a MES.

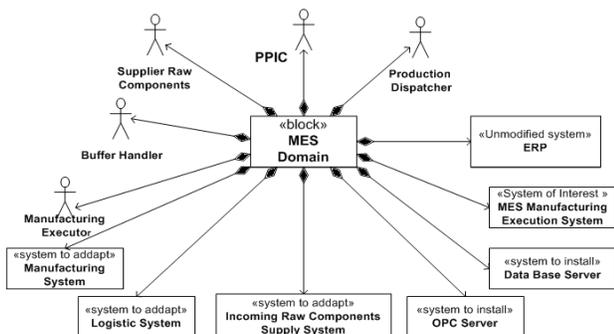


Figure 6. BDD Global

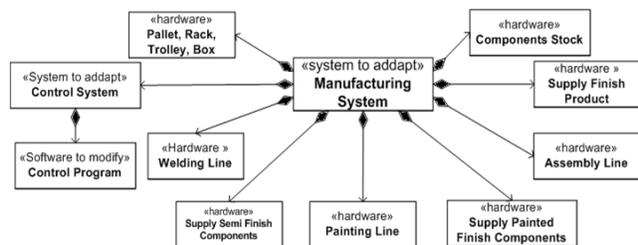


Figure 7. BDD Manufacturing System

Figure 7 depicts the manufacturing system architecture. Stations M1 (welding line), M2 (painting line) and M3 (assembly line) are the targets of operational performance measuring. Only control programs will have to be

modified. Must be installed supply material system for supply components to work station to assure production activity are running as schedule. The supply material system hardware consists supply semi-finished components, supply painted finish components and components stock system. To transfer components, provide pallet system consist pallet, rack, trolley and box which is assure the supply are wright in kinds, wright in quantity and at wright time as schedule. Also provide hardware to collect production output before the finish product to shipped.

Figure 8 depicts the logistic system architecture. Stations B1 for manage buffer and supply raw components, B2 for manage buffer and supply semi-finished components and B3 for manage buffer and supply finish components are the targets of operational performance measuring. Only Control programs will have to be modified.

Work station M1, M2 and M3 integrated to the MES system as shown in figure 9, the feature of this station in the MES is include in WorkCentre's. The setting up of a MES does not consist in designing from scratch a new tool but rather in configuring/adapting a generic MES to an existing system according to given project requirements. The structure of this MES is founded on the concept of components featuring a functional part for global variable declaration and their treatment, and visual parts for interaction with users. These components can be structured according to the physical model proposed by ISA (2000).

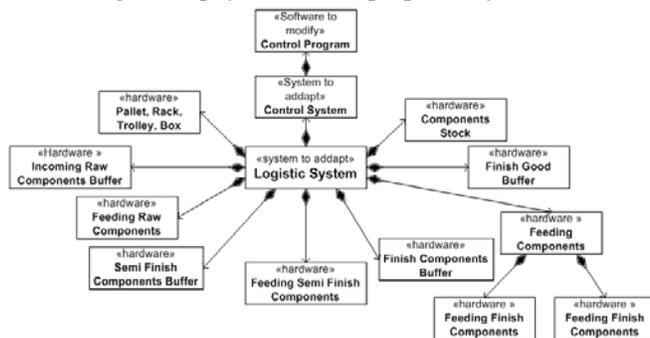


Figure 8. BDD Logistic System

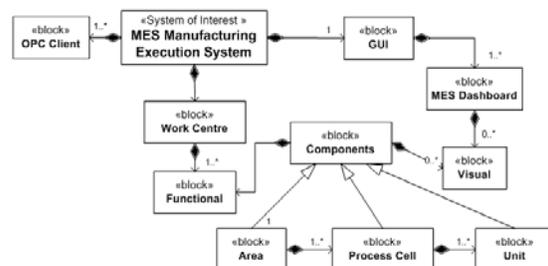


Figure 9. BDD Manufacturing Execution

In this model, we limit the scope to area, process cell and unit levels as higher levels go out of the frame of the workshop and the lower levels (equipment module and control module) are useless in this case. Furthermore, the MES can feature OPC clients (only one in this case), WorkCentre's (each work center represents an autonomous functional subsystem inside the MES) and a Graphical User Interface embodied by Dashboard. These Dashboard are made up of visual part of component instances whose functional part is located inside the work centers. Thus, the adaptation of the MES to a given production system consists in designing components, instantiating them in work centers and dashboard.

The sequence diagram of manufacturing execution for mode D minus 1 is shown in fig 10. In this model assembly process (M3) start 2 days behind M1 and 1day behind M2. In the first day has available WIP buffers in B1 of raw components to build a kind of product and ready fed to M1. In this day for this kind of product station M2 and M3 is in waiting state. In the day second has available WIP buffer in B2 and ready fed to M2, together with M1, M1 and M2 in production state but M3 is still in waiting state. In the day third has available WIP buffer in B3 and ready fed to M3. All WorkCentre's M1, M2 and M3 is in production state. In the day forth and so on all the Working Center's is in production state until job scheduled is finish. The production command signal send from production dispatcher as a task in feature of MES.

For the operational performance analysis purpose, the MES displays to the plant manager the state of each station (i.e. the value of indicators and, when necessary, the reason of production system consists in designing components, instantiating them in work centers and dashboard current breakdown), prints reports and exports indicators towards the ERP. Workers may need to supplement the information provided by the manufacturing system control, to refine the observed state in the MES. Actually, without the need of any actor intervention, the MES computes indicators over different time ranges: over the day, the week, the month, for instance.

Figure 11a is use case of MES using ISA 95, the integration of MES feature with another system and actor depict in this diagram. Base from production schedule triggered from ERP system command MES release dispatch command to change state of work centers to production state. Production dispatcher case plays a crucial role as other use cases are of use only if production system state monitoring is correctly performed.

Fig 11b is use cases of manufacturing system this figure depict the integration of manufacturing system feature with another system and actor. Connection use case manufacturing system with logistic system is use for assure availability of materials supply to guarding operational of work centers so detail function of logistic is depict in figure 11c uses case logistic system diagram.

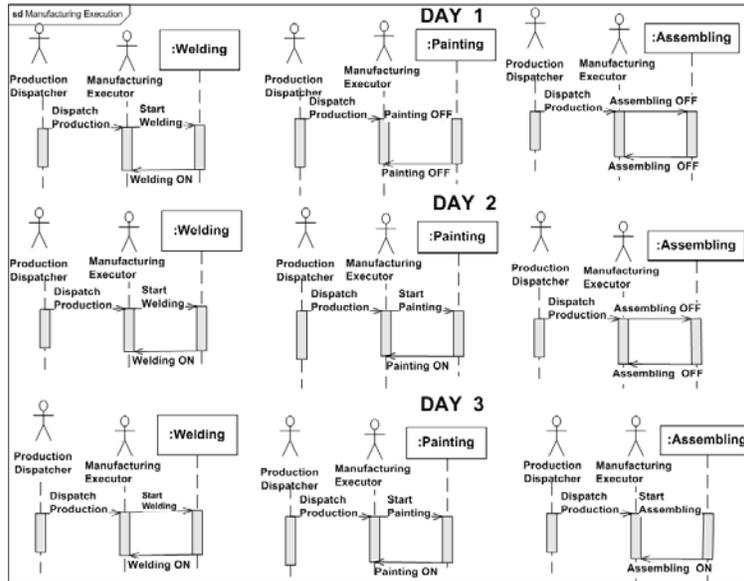


Figure 10. Sequence Diagram of Manufacturing Execution

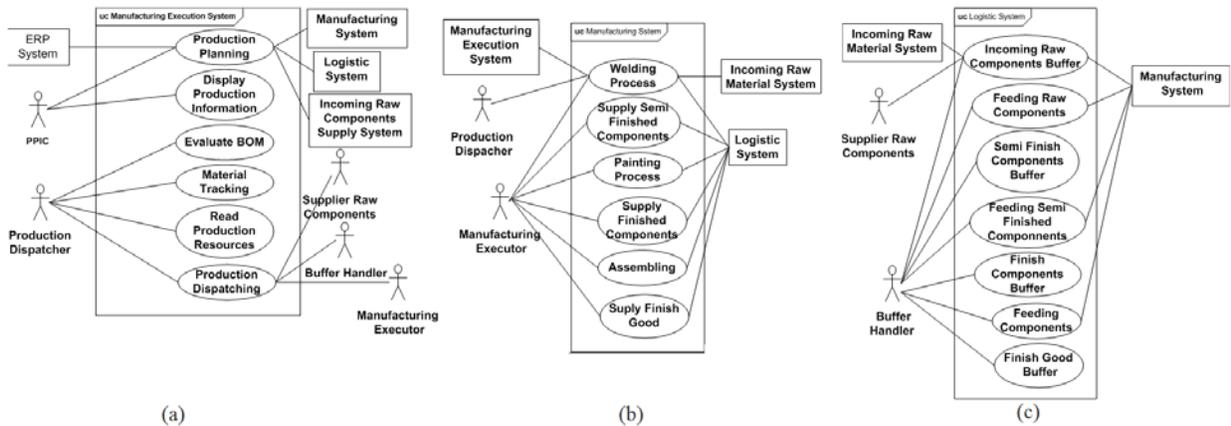


Figure 11. a) Use Case MES diagram, b) Use Case Manufacturing System Diagram, c) Use Case Logistic System Diagram

4.3. Design

4.3.1 Activity interaction between system

Figure 12 depict state machine diagram of welding process STM M1, and the activity of system feature to interact between system in activity relation of buffering, supply and production shown in figure 13. The Components model is instance of MES system (see fig 9), Raw Component Buffer and Semi finish buffer are instance of Logistic system , Welding station M1 are instance of Manufacturing system. Activity start from raw component buffer for supply components to station M1. Components release after instance component model give permit to transfer the components to fed welding station M1 for produce semi finish components. Semi finish components produce by M1 transfer to semi-finish WIP buffer as instance of logistic system. For activity painting and Assembling use another activity diagram. These activity diagram use to design communication of internal structure between system as seen in 4.3.2.

4.3.2. Internal Structure

Figure 13 introduces the instantiation of a part of the blocks previously defined in the Block Definition Diagrams (BDD) 7, 8 and 9. this figure adopted from Pietrac et.al (2011) study, with small modification mainly change of PLC with PC (personal computer) controller in station S1, the controller act as production dispatcher of MES system. Also PLC of work center controller change to PC controller.

Inside the Manufacturing System block instance, the central item is the Controller M1 block instance which represents the station M1 control. InterfaceM1 is instance of User Interface block, can be used by workers to change the functioning state of station M1; this is why they appear here. In the same manner, worker actions on Interface C1 can, by way of Controller C1, modify the afore mentioned state.

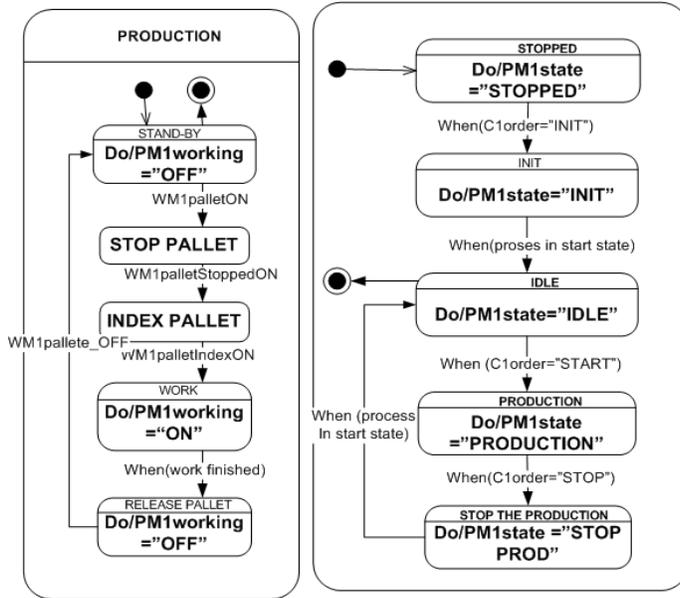


Figure 12. State Machine Diagram of Welding Process, STM

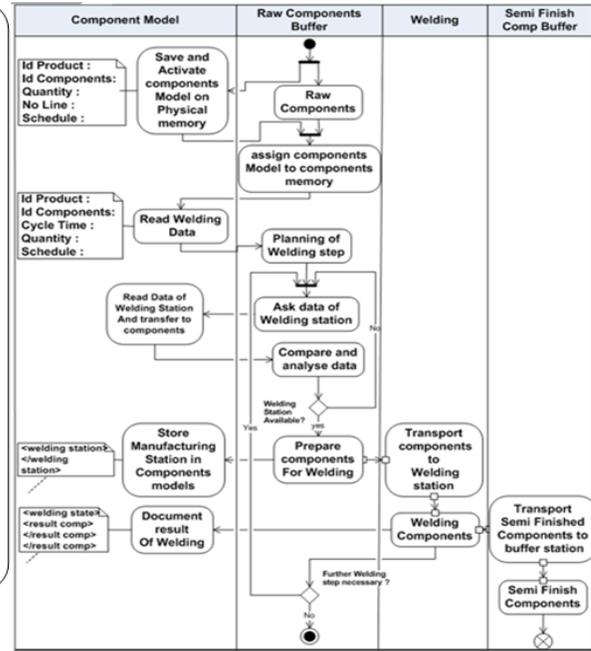


Figure 13. Activity Diagram of Welding

Diagram of figure 14 also features an instance of OPC Server block and an instance of OPC Client block whereas it does not display any instance of ERP nor Database Server blocks. As a matter of fact, the instance of ERP block exists but it is not used. The instance of Database Server also exists and is used for persistence purpose internally by the MES. It does not require any specific study so it is not necessary to display it.

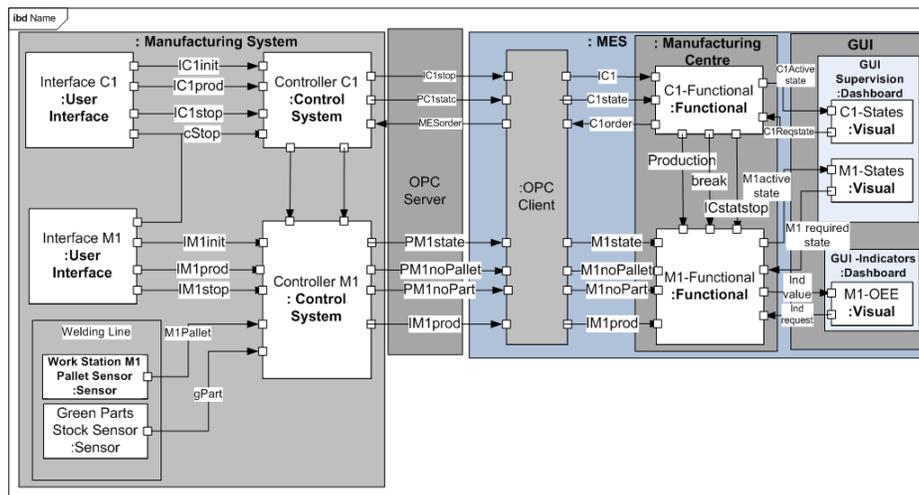


Figure 14. Internal Block Diagram of Manufacturing System and MES

From the point of view of the MES, the central element of the performance analysis is the instance M1 of a Process Cell (see fig. 14). This instance includes the instance M1-Functional of block Functional, whose role consists in monitoring state changes of station M1. It also includes two instances of Visual block: the first one, M1-indicators is used to display in real time WIP buffer indicators, different downtimes and their evolution. The second one, M1-States enables to monitor the changes of state of station M1.

At this step of design, Internal Block Diagrams are used only for the specification of the structure. Signals exchanged between blocks, although they appear in figures 15 and 16 will only be set through the drawing of State Machine Diagrams which represent the dynamics of each block instance.

4.3.3. Behavior

To measure performance of production system for this case overall equipment effectiveness (OEE) is use as an indicator performance which is represent five operational performance of ERP in the level shop floor. For this purpose, designed State Machine Diagram for M1-Functional, M2-Functional and M3-Functional (fig 15). Time sequence and time class which is use in these machine as shown in table 3. Time base of functionality of production activity states according to downtimes to observe. On this diagram, a state is created for each time to observe. Not every defined time class is used on every production system and, on the contrary, some of these classes may be used several times. Thus, in this system, some classical planned downtime like exchange of tool, periodical setting, quality control or scheduling maintenance are not used. On the other hand, the emergency stop, no pallet, no part is depending downtimes. Besides, the times Closed and Planned Shutdown have been grouped together in the Not Required state as it is not necessary to distinguish them for the analysis of the downtimes which could lead to a OEE decreasing (Pietrac et.al, 2011).

The initial and final states for these STM diagram (fig 16) are modeled by the not required state. Mode production is use production ON (welding, painting or assembling on) event, this event operate by the workers and is not observed on the production system. Indeed, during test, setup and maintenance phases, the production system may have exactly the same behavior as during real production phase. Therefore, it is not possible to decide only from the system observation whether this one is required for production or not. This diagram can be compared with the STM of Station M1 to emphasize the differences in state definitions from two different points of view (MES/OEE versus manufacturing system).

Table 3 States of Station M1, M2 and M3 as adopted from Pietrac et.al(2011)

| Time | Time Class |
|-------------------|----------------------------|
| NOT REQUIRED | Closed Planned Shutdown |
| SETUP | Self-Downtime |
| PRODUCTION | Operating Time |
| EMERGENCY STOP | Depend Downtime |
| NO PALLET | Depend Downtime |
| NO PART | Depend Downtime |
| STOPPED ON SYSTEM | Unknown Downtime |
| BREAK | Planned Shutdown |

In the same manner, production OFF, break ON and break OFF events are worker generated events. Notice that break ON and break OFF are events which have to be synchronized with the behavior of the production system. Indeed, when workers start their break, the system has to stop producing. Adding active states on life lines of instances Controller M1, M2, M3, Controller C1, M1-Functional, M2-Functional, M3-Functional and C1-Functional helps in highlighting relations between these states. This example highlights the necessity to separate MES OEE states from manufacturing system ones and to precisely model their mutual relations.

The drawing of diagram 16, which depicts different production and downtime states, leads to study the behavior of the manufacturing system from a performance analysis point of view. This study is performed with the help of Sequence and State Machine Diagrams. Setting up state changes induced by users also requires setting up GUI inside the MES. In order to render these state changes (inside the MES) onto the production system, one has to modify this latter behavior. On our example, it amounts to modifying evolution conditions of station C1. In the same manner every PC program is supplemented in order to enable data exchanges with the MES, which implies to update initial station STM diagrams such as the one seen in fig. 9.

This MES design concept does not stop at this modeling step (conceptual) it is mean that this integration requires the study of interactions between software components of the MES and software and hardware elements of

the manufacturing system, this would not have been possible without a preliminary detailed design (modeling) phase. Other Sequence Diagrams to control timing of production scenario D minus 1 in detail have been drawn but they could not be included in this paper.

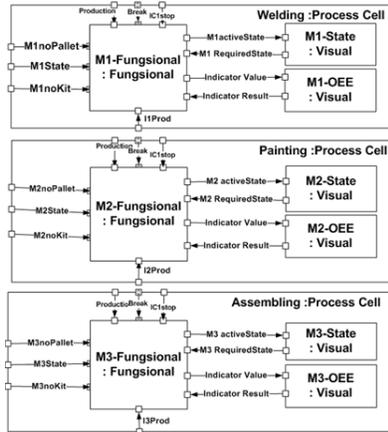


Figure 15. IBD of Production

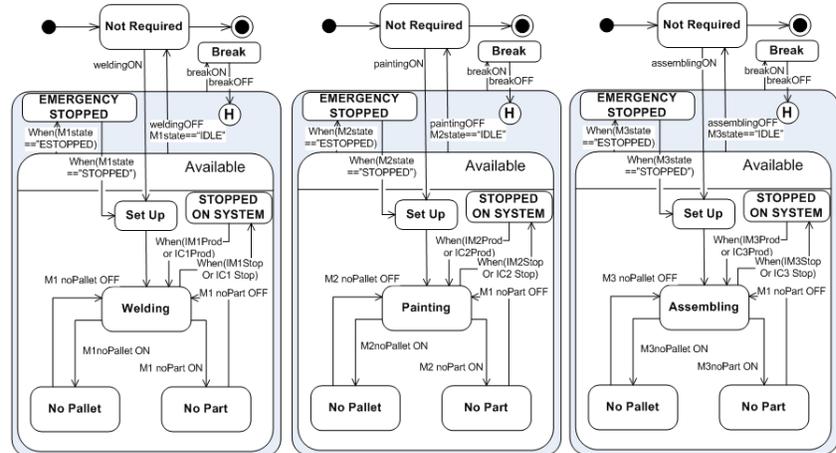


Figure 16. STM Diagram of M1, M2 and M3

The drawing of diagram 17, which depicts different production and downtime states, leads to study the behavior of the manufacturing system from a performance analysis point of view. This study is performed with the help of Sequence and State Machine Diagrams. Setting up state changes induced by users also requires setting up GUI inside the MES. In order to render these state changes (inside the MES) onto the production system, one has to modify this latter behavior. On our example, it amounts to modifying evolution conditions of station C1. In the same manner every PC program is supplemented in order to enable data exchanges with the MES, which implies to update initial station STM diagrams such as the one seen in fig. 12.

This MES design concept does not stop at this modeling step (conceptual) it is mean that this integration requires the study of interactions between software components of the MES and software and hardware elements of the manufacturing system, this would not have been possible without a preliminary detailed design (modeling) phase. Other Sequence Diagrams to control timing of production scenario D minus 1 in detail have been drawn but they could not be included in this paper.

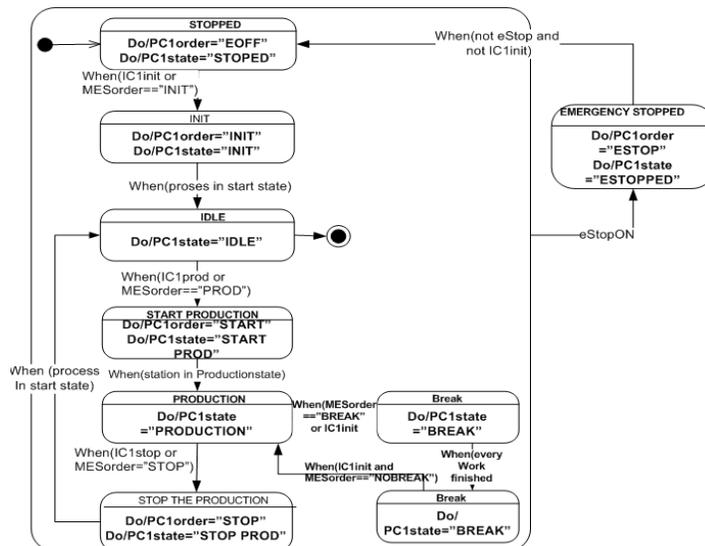


Figure 17. STM Diagram of Dispatcher Station C1 adopted from Pietrac et.al(2011)

5. Conclusion and Future Research

In this paper we studied to utilize existing ERP system modules with company environments and paired up MES within an existing manufacturing system. The result of the study is a concept to manage D minus 1 production

scenario used SysML language. Using SysML interaction of software and hardware elements of the manufacturing system can be arranged, and also showed that SysML is well suited for modeling MES paired up with its manufacturing system. In our future work, we will endeavor to provide a detailed process of development, analysis from specifications to the detailed design of the MES to be implemented in the production plant.

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Biography

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